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H. B. WALKER, President — **RAYMOND OLNEY, Secretary-Treasurer**

Vol. 6 — APRIL, 1925 — No. 4

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The Object and Scope of A. S. A. E. Activities

THE American Society of Agricultural Engineers was organized in December, 1907, at the University of Wisconsin by a group of instructors in agricultural engineering from several state agricultural colleges, who felt the need of an organization for the exchange of ideas and otherwise to promote the advancement of agricultural engineering. The object of the Society, as defined by the Constitution, is "to promote the art and science of engineering as applied to agriculture, the principal means of which shall be the holding of meetings for the presentation and discussion of professional papers and social intercourse, and the general dissemination of information by the publication and distribution of its papers, discussions, etc."

The membership of the Society represents all phases of agricultural engineering, including the educational, professional, industrial, and commercial fields.

The scope of the Society's activities embraces both the technical and economic phases of the application of engineering to agriculture, and is comprehended in the following general headings:

(a) Farm Power and Operating Equipment—power, implements, machines, and related equipment.

(b) Farm Structures—buildings and other structures and related equipment.

(c) Farm Sanitation—water supply; sewage disposal; lighting, heating, and ventilating of farm buildings, and related equipment.

(d) Land Reclamation—drainage, irrigation, land clearing, etc., and related structures and equipment.

(e) Educational—teaching, extension, and research methods, etc., employed in the agricultural engineering field.

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AGRICULTURAL ENGINEERING

The Journal of Engineering as Applied to Agriculture

RAYMOND OLNEY, Editor

Vol. 6 APRIL, 1925 No. 4

EDITORIALS

Revival in Power Farming

A STRIKING illustration of the tremendous impetus that will unquestionably be given to farming with mechanical power this year is furnished by the attendance at the power-farming schools of a leading tractor manufacturer held during the winter. A year ago there was a total attendance at these schools of 2995 in the United States; this year the attendance increased to 4960. This is an increase of 65½ per cent.

The increase in numbers, however, does not tell the whole story. The real increase came in the revived enthusiasm and the spirit of optimism shown by the dealers, owners, and prospective owners of power-farming machinery, which was apparent at all the school sessions, and which was 100 per cent greater than a year ago.

According to reports from other tractor manufacturers, this revival of interest in and enthusiasm for power farming is general. The factories are reporting a large increase in orders and a still larger increase in inquiries from prospective buyers, all of which shows that power farming has never been dead but merely dormant in the minds of the farmers.

An engineered agriculture, unquestioably the greatest need of American agriculture today, is dependent on the efficient and economic application of mechanical power more than on any other one thing.

GEO. W. IVERSON

The Purnell Bill

THE passage of the Purnell Bill has made it possible for Congress to appropriate additional funds to the state agricultural experiment stations for research in agriculture.

Progress in improvement of farm and home life has depended largely upon development of mechanical and engineering equipment and apparatus adapted to farm operations. However, research and investigation along these lines have been sadly neglected by the experiment stations.

All agricultural engineering departments have been requested to prepare research projects to be taken up under the Purnell Bill. Some phase of the use of electrical energy on the farm would make a good subject for the stations in any part of the country. There are many others of just as general interest, but there are subjects more important to certain regions than to others.

The experiment stations situated in those states where irrigation is an important farm practice could well outline projects in irrigation and drainage to be taken up under this bill. The factors that affect the movement of water in irrigated soils is a suggestion for one subject. This can be connected up with the movement of the underground water in drained soils. Laboratory and field tests should both be employed. As an application of the results of this kind of a project, the effect of the rate of movement of water in the soil has on the method of irrigation can be a follow-up project. From these projects might it not be possible to devise the best methods of irrigation for a given type of soil and subsoil having definite slopes? In other words, is it not possible to establish facts from which the best irrigation system can be designed for a given project after a topographic map and a soil survey map have been made? If so, the designing of an irrigation system can be placed on a scientific engineering basis the same as any other engineering design.

H. E. MURDOCK

American Forest Week

THE week of April 27 to May 3, designated by President Coolidge as American Forest Week, brings to attention various means of conserving forest resources. Until recently forest waste was in the same category as Mark Twain's weather about which everybody complains but nobody ever does anything. Recent legislation, both federal and state, has initiated steps leading towards reforestation and fire protection.

Legislation, however desirable, is a mattter for the state, as contrasted to the individual. Responsibility rests on the citizen as well as on the state. How can we fulfill this part of our obligation?

Collectively the American Society of Agricultural Engineers can back such proposed forestry legislation as has merit. There are states which still are backward in reforestation policies where steps should be taken.

Individually, members can probably exert the greatest influence in wise utilization of forest products, for it will avail but little if a permanent supply is assured by the state but the material wasted by the individual.

Forest products are necessary because they are economically desirable, and continuity of production should be assured. This contemplates both reproduction and conservation. Conservation, however, does not always mean refraining from cutting. It would have been wiser to cut some timber lands years ago because these trees have passed their prime and are now in a decadent stage, so that only a portion may now be utilized.

Failure to cut would not have preserved such forests, and cutting at the proper time would have permitted a new virile growth to take the place of the old stand. But all this, or any cutting, does not justify other than intelligent use, words which may convey a variety of meanings to different readers, depending upon their familiarity with the behavior of wood.

It will be apparent, nevertheless, that we should not waste. Rejecting a piece of timber because of fancied, instead of valid, objections to natural defects should be discouraged. At one time clear pieces of white pine were used for studding. At the present time we see joists rejected because of knot holes, despite the fact that government tests show definitely that a loose knot is frequently less detrimental to strength than a tight knot of the same size, because of less surrounding disturbance of grain. Evidently here is one place where the individual can aid in conservation.

Likewise, we should utilize so as to secure the greatest life or ultimate economy. Where conditions are conducive to decay, lumber should be given some preservative treatment, or when this is not feasible, or is objectionable on account of odor, etc., the use of woods with the greatest natural durability (cedar, cypress, redwood, white oak or chestnut) should be encouraged.

The subject is a vast one, but the message is short. The individual can give material service by utilizing forest products economically and intelligently so as not to dissipate the resources provided by Nature and the state.

L. P. KEITH

The Development of the Track Type Tractor*

By Pliny E. Holt

Mem. A. S. A. E. Vice-president and Director of Engineering, The Holt Manufacturing Company

I DO not pretend to be an authority on the history of the tractor industry. However, in touching upon the high spots of my experience of the past twenty-five or thirty years—inasmuch as that covers the development of the tractor industry to date—I will attempt to offer a perspective of some of the interesting things that manufacturers have encountered in bringing the tractor to its present place in the field of mechanical equipment.

Incidentally, the term "farm tractor" is somewhat misleading because—as those of you who have seen tractors grading roads, hauling logs, freighting across Alaskan snow-covered roads, or hauling supplies for oil exploration through unbroken jungles—the tractor of today is much more than a farm tractor, perhaps even more properly it might be called a piece of industrial equipment rather than an agricultural machine. But of that development more will be said later.

When I first came to California in the middle 90's, the tractor industry was in its infancy. It is rather a remarkable thing, when you come to think of it, that the tractor has become so important in a space of time comparatively so short. When you consider that agriculture is extremely slow in adopting any changes, and that other agricultural tools, particularly the plow, have changed little in design and not at all in principle in several hundred years, the development of the tractor is truly remarkable.

When I came to California, the steam tractor already had established a place in this part of the country. Those were the days of big land holdings—the days of what novelists call the land barons and soil robbers—and mechanical power was almost essential for carrying on cultivation in big units.

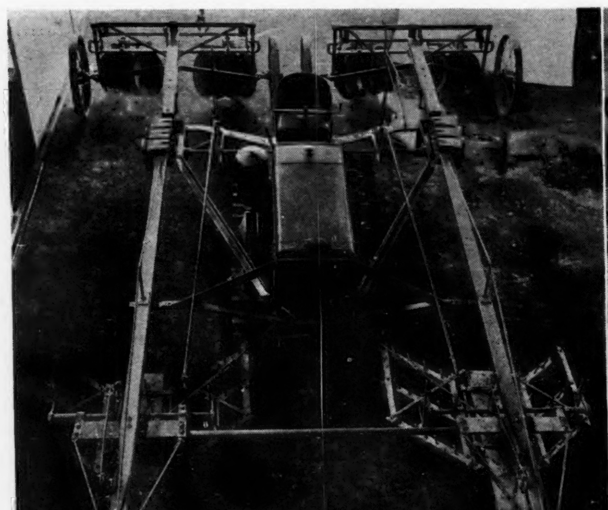
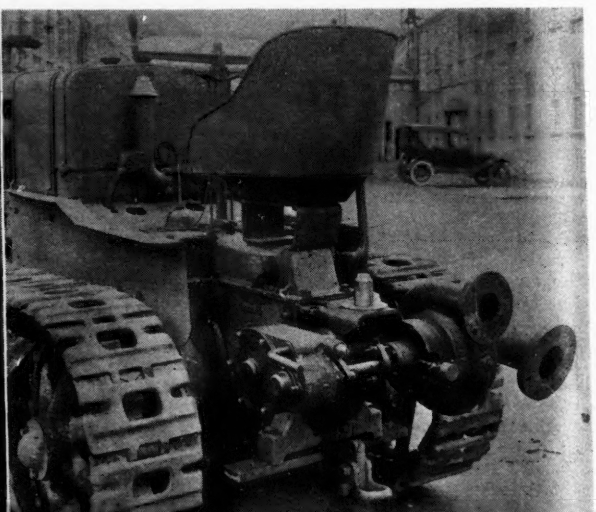
Benjamin Holt built a combined harvester-thresher in 1883. This machine cut a swath of grain eighteen feet wide and was pulled by twenty-four horses or mules.

The horses suffered considerably owing to the high temperatures prevailing in the San Joaquin Valley during the harvest season. Two years later a steam tractor was developed to pull these machines.

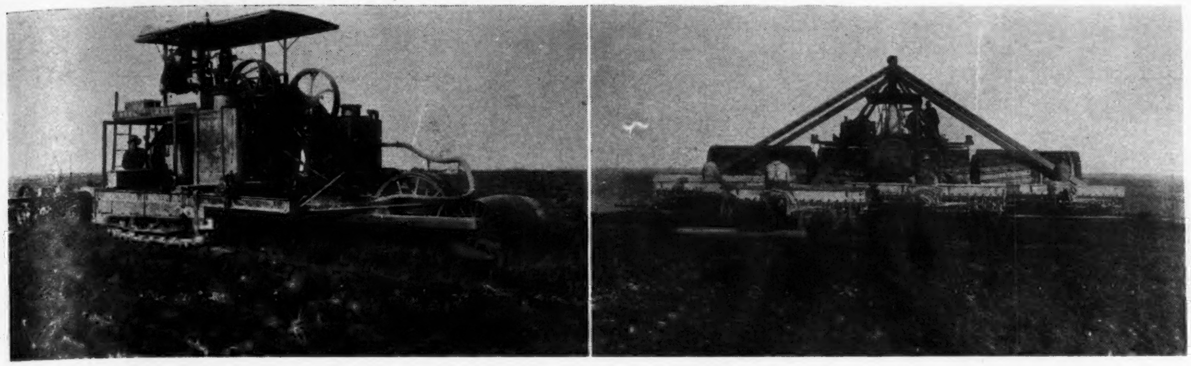
It is interesting to note that the earliest steam tractors built in California were for drawbar work. About 1875 Captain Roberts built several large steam tractors known as "road locomotives". These were used to haul long trains of wagons loaded with grain from fields in the Sacramento Valley to his steamers on the River. Later steam tractors for drawbar work were built by Daniel Best and Benjamin Holt. While first used for pulling combined harvesters, they were soon adapted for plowing. It was in this work that the need for better traction for the soft ground early became evident.

Just before coming to California, I had witnessed in Chicago, on Thanksgiving Day 1895, an automobile road race from downtown Chicago to Evanston and return. The participants in that historical event were the Winton, the Elwood Haynes, the Duryea, and the Benz, the latter a French make. There were several others, but I cannot recall their names. At any rate, it was a great event and it sent me on West with all sorts of enthusiasm about the gasoline engine. I first released some of this bottled-up enthusiasm by building an automobile in the fall of 1896. It wasn't much for looks—the frame and running gear were parts of a discarded street sweeper, the wheels had steel tires, the transmission was through chain drive, and though there were two speeds forward, there was no reverse. People said; "There's no use of putting in any gearing to make it back up; you want a horseless carriage to take you somewhere, and the only way it can do that is by going ahead." Well that machine ran. The power plant was a single-cylinder gas engine and the streets of Stockton were rough, and, as I have said, the wheels had steel tires

*From a talk before a meeting of the Pacific Coast Section of the American Society of Agricultural Engineers, Berkeley, California, December 12, 1924, supplemented by an interview with Mr. Holt by L. J. Fletcher.

(Left) Tractor equipped with asparagus-cultivating equipment. (Right) Tractor equipped with centrifugal water pump



(Left) The first Holt "Caterpillar," steam driven. (Right) Round wheel steam engine used in farming delta lands

so one could hear my machine coming a long way off. Stockton was quite a trading center and all along the main street were hitching rails to which horses and buggies or wagons were tied. The first triumphal trip down the main street caused so many runaways that the city authorities declared the machine a public nuisance and journeys thereafter were confined to the outlying sections.

In justice to myself I should explain that I produced a somewhat more creditable machine the following year. It had pneumatic tires which Morgan and Wright had just placed on the market. It had a tubular frame made up of boiler tubes. It had a differential and steering knuckles, and was really quite an automobile for its day.

But the idea of building automobiles was never very seriously considered by our company and at first it was even difficult to get much consideration for the idea of using gasoline power for any of the other equipment we were building. Steam was powerful and fairly dependable, and in spite of the weight and the difficulty and expense of hauling water and in some cases of providing fuel, steam was thought to be the one and only really practical source of power for heavy work. I remember when the use of gasoline power for tractive work was first suggesed to my uncle, Benjamin Holt, he remarked: "What! do you expect that popping thing to do any real work?"

The first opening wedge came in connection with power for our combined harvesters. There were and are many objections to operating the harvester mechanism from the main wheels of a harvester, and already we had put out some harvesters that carried an auxiliary engine operated by steam from the traction engine boiler. But it was finally conceded that a gasoline engine, though unfit for the heavy work of propelling a tractor, **might** serve—and the word "might" carried a big question mark—to operate the harvester mechanism. Well, we tried out a big single-cylinder engine first, and you can imagine what happened. In the first test the machine jumped off the supporting trestles and hopped all over the yard before we could stop it, so our experiment seemed doomed to a dismal ending. But we tried a four-cylinder motor soon after that, with such success that the Holt Company has consistently continued in the use of the four-cylinder type as the most desirable gas engine for heavy-duty service.

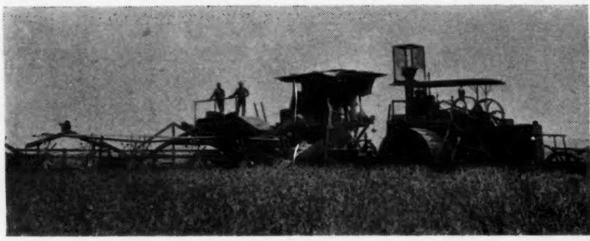
In the meantime, however, development was being made along another line—along the line that has made our product distinctive and that has been chiefly responsible for what success our company has enjoyed. I refer to the endless-chain type of drive member—the platform wheel as we first termed it—or the "Caterpillar" track as we soon aptly named it and later gave it the trademarked designation.

Perhaps some of you have visited the island section of the San Joaquin and Sacramento River Delta in California. You know the soil is soft and spongy, apparently without bottom, so light and fluffy that continuous cultivation lowers the surface, of so unsolid a character that one can feel the ground tremble as a person walks by several feet away. The cultivation of those areas with tractors offered a real problem in the days when a tractor was a big round wheel steam engine. Yet we tried to solve the problem. We put extension rims on the regular drivewheels. (The front wheel carried sort of a big steel drum.) Then we added extensions to the extensions. By the time we had extended the wheels so that they finally reached out eighteen feet on each side of the machine, we had to run a big A-frame truss over he top of the tractor to support the frame work on which the wheels turned. And by the time we had done all that, the additional weight had largely offset what advantage we had gained by making increased wheel surface. Yet those big ungainly steam tractors worked and were, compared with any other power than available, a huge success; that is, they worked if they were kept moving while in the fields. If stopped long in one place they would settle until in a half day's time a tractor might sink in as far as the axles, and in some cases completely out of sight, requiring a dredge to excavate them.

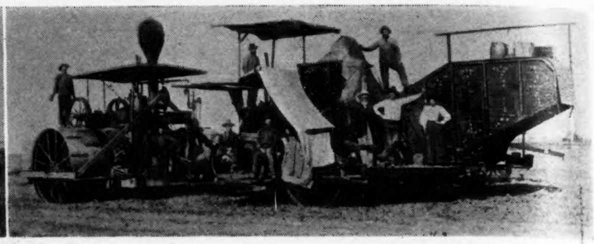
That island country presented an extreme condition, an almost unbelievable condition, but there was a great deal of land of that character right close at hand—our immediate interest—and also along certain sections of the Columbia River and in the marsh districts of the Middle West, and in Florida and Louisiana if we wanted to go farther. So Benjamin Holt developed the platform wheel, and it worked. It was first put on a steam tractor as an auxiliary to the regular wheels, then in place of the regular wheels, and it is impossible for you to imagine the amazement with which we, who had seen the big steam tractors with mammoth drivewheels go out and have difficulty keeping up on soft ground, saw the comparatively small endless belt keep the tractor up on the ground. Furthermore, the tractor not only stayed up on the soft ground but, partly because so much excessive weight had been eliminated and largely because the tractor no longer had to use up a large share of its energy to climb out of the depression its wheels created, the new track-equipped machine had amazingly greater useful power than the same machine had produced when equipped with wheels. The first time we really and fully appreciated the value of the tracks was when a 40-horsepower steam tractor equipped with tracks actually outpulled with ease a 60-horsepower round-wheel steamer.

Incidentally, it was this latter point that it was hardest for us to drive home with our prospective purchasers and with the general public. It was conceded that the "Caterpillar" track was a unique and valuable device for soft ground work, but it was at first generally considered a freak, limited in usefulness and adaptability, and it was a long time before it was recognized that the track type of machine was also essential for work in sand and over rough ground and, even more than that, that it offered positive ground gripping contact that insured highest efficiency in the conversion of motor power into drawbar pull.

To go back to the steam "Caterpillar," however, when we saw how compact a driving member the endless belt track provided, we began to consider how much further the idea of compactness could be developed by the adoption of the internal-combustion engine. Then was developed the



(Left) Steam traction engine and steam combined harvester.



(Right) This outfit of 40 years ago has primitive power take-off

"Caterpillar" gasoline traction engine that was the forerunner of the "Caterpillar" tractor of today.

We—meaning all of the tractor manufacturers—all had much the same early troubles and problems to solve. We had to overcome the popular prejudice of farmers against change of any sort in their methods and equipment. We had to overcome the propaganda of the horse breeders' associations which fought the tractor because they feared the effect this new industry would have on their business. We all had to educate our customers in the care and operation of tractors. Our branch of the automotive industry is closely related to the automobile business in some respects, but in others it differs widely. We recognized right at the start that the tractor motor operates continuously at full load, while the automobile motor operates at full load only when traveling at maximum speed or climbing steep grades. I believe it has been figured out that the automobile engine averages 20 per cent load in operation, while the tractor engine averages 85 per cent. We, therefore, designed our motors, cooling systems, lubricating systems, etc., to stand this heavy duty. But the tractor is handicapped in another respect. When the automobile gives some trouble, it can be driven or towed into a convenient commercial garage for repairs. The tractor must, in most cases, be repaired in the field. The tractor manufacturer must be prepared to provide competent service, either from his own organization or through dealers. He must provide his customers with more complete instruction literature when the tractor is delivered than the auto purchaser requires. Some of the manufacturers even issue service bulletins at frequent intervals. Some conduct owners' and operators' instruction courses at their factories or branches. In the early days this used to be an even greater problem than it is today. Then even the universities hesitated to give this innovation in farm power such recognition as would be implied by giving instruction in tractor care and operation. Later, however, the agricultural colleges gave regular courses in these subjects. Some gave special short courses and a few went so far as to carry these courses out through the farming communities with traveling tractor schools.

Gradually the field of the tractor broadened far beyond its original confines of solely agricultural work. In the case of our own company even in the early days when we sold a fleet of twenty-eight tractors to haul supplies across the Mojave Desert for the construction of the Los Angeles Aqueduct, we did not realize what tremendous possibilities there were for the use of tractors outside of agriculture. It was really not until the World War that the extent of the industrial field began to be realized. You know the part that tractors played in the late war, and perhaps you know how extensively they are now used for road grading, contract and similar work. You have undoubtedly seen rubber-tired tractors pulling drays on the city streets, and in the yards of industrial plants. The tractor of today has developed into a machine of all-around usefulness—the sort of equipment that offers the natural and logical solution for the problem of how to handle difficult tractive problems of every sort.

Possibly you will be interested in some of the problems that have been more or less peculiar to our industry. One thing is the human element. The human element in tractor operation and success is a most important one. It is important that the tractor should not only be powerful and enduring, but also easy to care for, easy to handle and comfortable to ride, so that the driver, even if he is not the actual purchaser of the machine, will be a booster for it.

A tractor must be designed to certain limits of height, to work in orchards under low-hanging branches. It must be designed to certain limits of width to work in vineyards and in cultivation of sugar beets, aspargus, etc.

It is necessary also to maintain good ground clearance and particularly to avoid any projections of the truck frames or other stationary parts, close to the ground on which all or part of the weight of the tractor may be borne on rough ground, or in crossing ditches.

Another thing to which a great deal of study is being given is the matter of lubrication. Efficient lubrication is, of course, essential in all tractor work, but in most agricultural work the problem is complicated by reason of the fact that in many localities during a large part of the working season, the tractor operates in heavy clouds of dust. It does not take a great deal of this dust mixed with oil to change it from a lubricant into a grinding compound. Every precaution is now taken to close the crankcase of the engine at every point with the best possible dust seal, and to arrange breathers so that dust cannot enter. The matter of dust is important not only in connection with the engine, however, but also with all bearings, such as the truck wheels, front idler and final drive bearings. We use heavy fluid oil for lubricating these parts and find it has an advantage over grease in that it can be fed to the bearing in excess of actual requirements, the excess oil washing out the dust and leaving clean oil for lubricating.

The success or failure of a tractor in the field is largely a matter of giving proper care and attention to lubrication. If lubrication and adjustments are properly attended to, repair and upkeep are greatly lessened.

Reference has been made to our efforts to keep dust away from moving parts. It is also essential to keep dust from gaining entrance through the carburetor. That is another point to which very careful attention has been given. All the air that enters the carburetor is filtered through an air clarifier. We have clarifiers now that are

The great annual get-together of agricultural engineers—the nineteenth annual meeting of the American Society of Agricultural Engineers—will be held this year at Madison, Wisconsin, June 22, 23, 24 and 25, 1925. It is the premier event of the year in the agricultural engineering profession.

nearly 100 per cent efficient in respect to removing dirt and dust, but they require some attention from the operator two or three times a week, or even once a day under extreme conditions, to clean the clarifier and wash out the dust that has accumulated in it.

I have referred to the efforts that have been made to increase the life and endurance of tractors. It is not, of course, possible to eliminate entirely the need of repairs but we take this point into consideration in design and one of our purposes is to keep unit parts down to a size and weight that make it possible for one or, at the most, two men to handle any part of the tractor.

In conclusion, one may consider briefly what the future development of the tractor will be. I do not suppose any of us are qualified to speak with any authority on this subject, but we are all privileged to let our imaginations work in that direction. Insofar as refinements in design and construction are concerned, I believe the entire industry is working along the right lines, and efforts in that direction will undoubtedly be continued by all of us.

I believe the tractor is now in its third and final stage of development. The first stage was that early period when the tractor was deemed a success when it would propel itself up and down the roadway in front of the factory. The manufacturers and buyers were both enthused with the fact that the machine actually operated and surprisingly little attention was given to any economic use of the machine itself. The second stage was that period when the tractors were largely judged upon their ability to do work, such as pulling a certain number of plows, feet of disk harrow, etc. Tractor demonstrations were used largely to convince the farmer that these machines would actually do the work in the field. The main questions asked were: "How much does the tractor cost?" and "How much will it pull?" The third or present stage of development is the one in which the successful tractor manufacturer is successfully answering such questions as: "What is the cost per hour for operating this tractor at full load?", "How long will it last?", "How well is it protected against dust, and how accessible is it for repairing?",

I believe the biggest possibilities for the future lie in the direction of increasing the field of usefulness of the tractor and making it fit better into the working programs of its purchasers to effect higher efficiency. Already we have made some progress in the way of equipping tractors with generators, water pumps, and other attachments.

I believe that the next forward steps will be along a line in which the American Society of Agricultural Engineers has recently initiated some research work—that of developing a standardized power take-off which will mean a more extensive use of the tractor's power to operate the mechanism of tools pulled by the tractor. We have done some work along those lines and are cooperating with others in that work. Within the past month we have assigned a member of our engineering staff, who devotes his time exclusively to cooperating with other manufacturers who make tools used with our tractors, to devise hitches, attachments, power take-offs, and so forth. The fullest possibilities in this direction cannot be reached by the single efforts of any individual manufacturer, however, and it is our earnest hope that some means may be devised whereby close cooperation in this work can be effected.

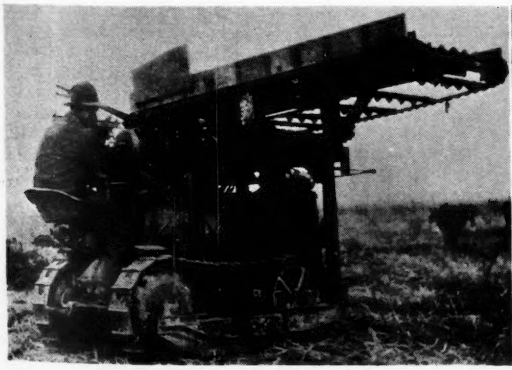
A Mechanical Manure Loader

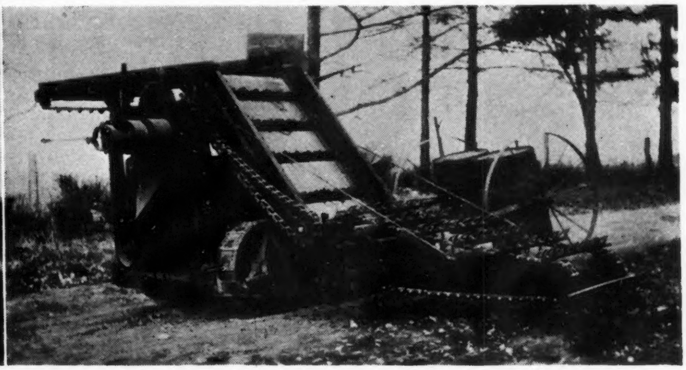
By E. R. Wiggins

ONE of the very recent developments in agricultural engineering along the line of farm machine design is that of a mechanical manure loader on Hawthorn Farm, Lake County, Illinois. In the paper entitled, "Growing 1000 Acres of Corn on Hawthorn Farm," presented by the writer at the eighteenth annual meeting of the American Society of Agricultural Engineers, at Lincoln, Nebraska, in June 1924, the following statement was made: "What is needed in hauling manure on this farm is a power manure loader. Such a machine is being built for Hawthorn Farm and will be used this present season. It is calculated this machine will replace 5 or 6 men in the yard and do the work faster than it is now done."

The machine referred to has been completed and tried out and its operation has been satisfactory to J. C. Reuse, manager of Hawthorn Farm. In a number of trials the machine loaded a 70-bushel spreader in 2½ minutes, but during any given hour it did not load more than fourteen loads. I believe that when the operator and spreader drivers become better acquainted with the operation of the machine eighteen loads an hour will be closer to the average. The time lost is that due to the intervals between spreaders and to the moving of the tractor from one part of the yard to the other.

The general design of the loader is shown in the accompanying illustrations. Mounted on the top of a tractor the drag carrier draws the manure to the left under the carrier to the main elevator where the manure travels over the top of the tractor and is delivered to the spreader. In addition to the drag carrier being arranged for tilting, the entire machine can be raised or lowered. The rack and pinion for tilting is operated manually, while the drag carrier is raised and lowered by a cone clutch. The machine is driven off a pulley at the front end of the engine.





(Left) Rear view of the mechanical manure loader showing the delivery carrier to the spreader. (Right) Front view of the loader; the drag carrier is shown at the extreme right

Research in Agricultural Engineering

Research activities in the agricultural-engineering field are presented under this heading by the A. S. A. E. Research Committee. Members of the Society are invited to discuss material presented, to offer suggestions for timely topics, and to prepare special articles on any phase of agricultural engineering research

The Sliding of Metal Over Soil

By M. L. Nichols

Mem. A. S. A. E. Professor of Agricultural Engineering, Alabama Polytechnic Institute

REQUESTS from persons in the farm equipment industry have prompted the presentation of the following data. It is realized that this is not an answer to all the perplexing questions of the implement designer, but it is hoped that the localizing of the questions involved may be of some benefit. The object of the study is to determine what constitutes the so-called friction of soil and metals, and something, if possible, of the nature of underlying variables affecting it.

In this work an effort was made to determine something of the properties of the materials which are worked with in ordinary field tillage, but no attempt was made to account for all the dynamic, physical, chemical, and biological complexes which field work introduces. It is also true that the results must be rough approximations, as is the case with all laws of friction, and wide limits of error must be allowed with all physical determinations of this nature with such constantly varying material as soil.

Methods of Study

In these studies the primary equipment was a piece of flat metal (chilled plow iron—area, 24.52 square inches) pulled by a spring balance. The coefficient of kinetic or sliding friction (U') was used and is the tangent of the angle of friction $P \div W$ (scale pull divided by weight.) Three points were located to determine this angle. These were obtained by adding weights to the slider of double and triple its weight (1,500 grams). The soils used were synthetic. A very finely divided clay of great plasticity, 98.6 per cent of which passed through a 100-mesh sieve and the balance going through an 80-mesh sieve, and a clean, round-grained white quartz sand, were mixed together to give soils of the following mixtures:

Sand 100 per cent	—	Clay 0 per cent
Sand 75 " "	—	Clay 25 " "
Sand 50 " "	—	Clay 50 " "
Sand 25 " "	—	Clay 75 " "
Sand 0 " "	—	Clay 100 " "

The following is a sieve analysis of the sand:

Number of meshes per inch	Per cent retained
20	0.0
40	4.0
60	4.5
80	16.8
100	39.3
over 100	35.4

In these preliminary studies exact determinations of the colloidal content of the soils by such methods as those developed by Gile and his associates (1)* were not made, but observations of the rate of settling and per cent of hygroscopic moisture indicated a high percentage of very finely divided material in the clay and very little in the sand. Moreover, the separations of colloidal material obtained by churning and centrifuging, which were used as a check, clearly indicated that the properties of the clay were largely determined by these small particles which is in accordance with the generally accepted facts brought out by Hilgard (6), Middleton (2), Ashley (3), Davis (4) and numerous other investigators.

The soils were air dried and water was added in various amounts to determine the effect of moisture. It is almost impossible to add small amounts of water to clay soils uniformly and obtain a homogenous product by simple mixing. A method of accomplishing this was arrived at, however, which is more rapid and apparently more accurate than other methods which are discussed in the literature available. A 6000-watt electric heater was connected with a small tank of such capacity as to quickly generate steam and furnish enough moisture for the quantity of soil used. The steam jet was carried over an atomizer so adjusted that the jet drew an additional amount of water, which it could vaporize. This reduced the steam temperature so it was near the point of condensation when it come into contact with the soil. The soil condensed the moisture on itself. The soil was also constantly stirred when subject to this jet of low temperature water vapor, and it was found that the moisture content could be raised to a very high per cent and the soil be very uniformly wetted without puddling. The gradual uniform change of color of the soil gives an index to the reliability of this form of moistening. The rise of temperature in the moisture films also seems to work against the puddling effect, which is a source of error in this kind of work.

Although agricultural engineering literature contains many references to the friction of soils and metals, no reference to specific or definite work on this subject could be found, except where static friction is concerned. This has been studied with respect to the supporting power of soils for buildings and its angle of repose as affecting various embankments or excavations. While data of this kind is not directly applicable, it has been used by Lindgren and Zimmerman (5) as the only basis in developing a theory of plow design by assuming the coefficient of sliding friction to run over the same range (0.25 to 1.01). While the results of the laboratory studies reported herein show this assumption to be correct for a large percentage of soils in "plowing condition" it does not account for the condition of the "push" or "putty" soil (6) of the cotton states. Nor does it give the designer an intelligent idea of what is taking place.

General Laws of Friction

Friction has been studied quite carefully by various technologists such as lubricating engineers, ship designers, etc., and in many cases proven theories of mathematical accuracy are available (7). The general conception of friction which seems to be used by engineers is illustrated by the following quotation from Morely and Inchly (8):

"Within certain limits the sliding friction between the surface of two solids in contact follows four simple laws:

*The numbers in parenthesis refer to the literature cited following this article.

"(1) The magnitude of the friction is proportional to the total pressure between the two surfaces.

"(2) It depends upon the roughness of the surfaces and upon the material of which the surfaces are made.

"(3) It is independent of the areas of the surfaces.

"(4) It is independent of the speed of sliding.

"These laws are true within the pressures and speeds probable in simple laboratory apparatus, but they are not actually true at very great speeds and pressures."

Between lubricated surfaces the friction varies with the viscosity of the lubricant, pressure, speed and area of contact. With liquids the resistance to motion is quite unlike those of solids, as they increase greatly with increase of speed and with area of contact and are independent of pressure.

In soils are encountered frictional conditions which vary through the entire category of soil types and in many cases we are more concerned with adhesion, or as Sir George Greenhill termed it, "stiction", than friction as the term is commonly understood.

In the following cases mentioned but a few instances have been selected as typical of the mass of data accumulated, but all figures represent an average of a number of determinations under the same conditions.

Pure Sand and Chilled Iron

Determinations of friction were made with sand at the following moisture percentages: Air dry, 0.5, 2, 4, 6, 8, 10, 12, and 15 per cent. Great care was used in getting a uniformly smooth track for the slider, compressed as firmly as possible without bringing moisture to the surface.

Dry Sand. In air-dry sand, U' was found to vary with the speed as follows (1500 grams of chilled iron and loose light soil):

Speed-mm. per min.	U'
1760	.400
4600	.500
5600	.533

In general, this increase in friction with speed was found to hold true for all soils in which the bearing power was not sufficient to hold the weight of the slider. In dry sand the slider would roll a considerable volume of soil under it, giving a friction somewhat analogous to the skin friction of a ship moving in water. Undoubtedly this action would enter into high speed plowing and would partly explain the increased draft with increased speed found by Davidson and Fletcher (9) and Collins (10). Moreover, increased speed would increase the moldboard and other pressures caused by throwing the furrow slice further and producing greater pulverization. This in some cases might account for a failure to scour. If the moldboard pressure is increased by high speed plowing when the adhesive force of the soil to the moldboard metal is nearly equal to the force of cohesion in the soil, this would undoubtedly be the case. This may explain the case found by Collins (10).

With soil of this low bearing power it is to be noted that the friction varies in direct proportion to the weight per square inch rather than directly as the total weight, as is the case between solids. In other words, it is not independent of the area of contact as shown by the following relation of U' to weight—Chilled steel on air-dry sand (light loose soil):

Wt. per sq. in. bearing	U'
36.4	.185
43.4	.222

A very careful study was made of this particular point, as traction on a light soil is a very difficult problem. That these questions are of fundamental importance in plow design is obvious. Atmospheric temperature and humidity differences were also found to be of sufficient weight to produce slight variations in the results on different days.

The smoothness of surface is also an element of variation. Highly polished chilled steel gave a coefficient of 0.185 while a smooth but unpolished surface of the same metal gave a coefficient of 0.388.

Medium Moisture Ranges. Between 2 and 4 per cent moisture content, the sand suddenly increased in bearing power and U' decreased to 0.266 and did not vary with the speed. There was no apparent motion beneath the surface of the sand. It was found, in all cases in which the bearing power of a soil was sufficient to hold up the slider, that the value of U' was a constant up to a certain percentage of moisture.

At 6 per cent moisture the friction was constant as long as the slider was kept dry. However, the repeated running of the slider over the same track brought a film of moisture to the surface, which adhered to the slider. Whenever this occurred, there was an immediate increase in pull caused by the necessity for breaking these films from their attachment to the surface. It was noted that when this occurred an electrical current was set up having a potential as high as 0.2 volt. This potential may possibly be due to physical-chemical forces since the soils studied contained iron salts. However, it is considered doubtful if sufficient iron compounds were present in the soils to give this difference in potential. It is to be noted, however, that at this point the adhesion of the soil studied first came into prominence.

At 8 per cent moisture content this effect was still more noticeable and it is also to be noted that when the slider became wet the pull varied directly with the speed. The following summary of a number of tests at a constant speed illustrates the increased pull, due to the adherence of moisture:

Effect of Moistening the Metal Surface on U'

(Wet and dry slider — soil at room temperature)

Slider dry			Slider wet		
Wt.-gm.	Pull-lbs.	U'	Wt.-gm.	Pull-lbs.	U'
1500	400	.266	1500	500	.333
3000	800	.266	3000	1000	.333
4500	1200	.266	4500	1500	.333

Another interesting fact, previously noted by Bacon (11) was that whenever the slider was heated the friction, i. e., U', decreased in all cases whether the slider was dry or wet. In the above case the friction with a hot slider was as follows:

Heat Effects

(Hot slider — soil at room temperature)

Wt.-gm.	Pull-lbs.	U'
1500	350-375	233-250
3000	700-750	233-250
4500	1050-1100	233-244

On the other hand, when the soil was heated the pull increased. On careful observation the action appeared to be as follows: When the warm soil struck the cold metal the moisture films immediately in contact were chilled and adhered to the metal. Below these were films of higher temperature and consequently of lower viscosity or lower surface tension. This meant that the lower films were broken and the shear of the moisture films was distributed over a larger area, giving a total increase in pull. Probably the relative temperature of the plow bottom and the soil and the variations in the moisture content together are the factors that cause the various sticky spots in the field operations noted by Bacon (11). Temperature has a great effect on plasticity and adhesiveness since these properties are functions of the surface tension or free surface energy of the film surfaces. This decreases rapidly as the temperature increases and becomes zero at the critical temperature. This decrease is often linear, as shown by Harkins (13) who developed the most fundamental relations in connection with surface energy by the applications of the principles of thermodynamics. The thermodynamics of these saturated films has also been treated by Freundlich (14), Dupre (15), Lord Rayleigh (16), Gibbs (17), and Einstein (18), and it is felt that the general principles developed by these men offer promising tools for the unlocking of these soil problems.

Theory of Adhesion

Since it was found that the moistening of the surface of the metal seemed to indicate a point at which adhesion takes place and that adhesion is the so-called frictional property of the soil which the designer is chiefly interested in, it would be well to look into the theory underlying this phenomenon. The results obtained quite conclusively show that adhesion is a function of the soil moisture films and without doubt it is the relative surface tension of these films which affects this process. This is well set out by Harkins (13) who shows that the work of adhesion is equal to the sum of the surface tensions minus the tension of the interface, or expressed mathematically:

$Wa = Ta + Tb - Tab$, and that $Ea = (Ta + La) + (Tb + Lb) - (Tab + Lab)$, where Ea is the total surface energy, Ta and Tb the surface tensions of the surfaces in contact, La and Lb the respective latent heats, Tab and Lab the tension and latent heats respectively of the interface.

He states that a liquid will spread if its work of surface cohesion (Wc) is less and will not spread if its work of surface cohesion is greater than its work of adhesion (Wa), with respect to the surface of the liquid or solid upon which the spreading is to occur. The spreading coefficient, S, gives a measure of the tendency to spread and is defined as:

$$S = Wa - Wc$$

This expression exhibits the extremely simple relation that spreading occurs if the adhesion between the two liquids or surfaces is greater than the cohesion in the liquid which is in the position for spreading, while spreading does not occur if the cohesion is greater than the adhesion. It is obvious that a positive value of the spreading coefficient corresponds to spreading and a negative value to non-spreading.

This not only gives a logical explanation of the results obtained with soil, but suggests a method for studying the adhesion of soil to metals and shows that the incorporation in tillage tools of a metal giving the lowest value of S with a soil solution would be the most desirable for adhesive soils.

Harkins further states in discussing the spread of liquids upon metals, "Experiments with mercury show that the spreading coefficient for water is high, and much higher (from 60 to 137) for all the twenty-nine organic liquids tested. Thus all these liquids and probably all other organic liquids should spread upon this metal and presumably upon the surface of all other metals. * * * * * Water does not not spread upon an ordinary surface on mercury on account of the contamination of the surface by various substances, but spreads readily when the mercury is distilled in a vacuum in clean vessels, as found by Rayleigh" (20). Thus it will be seen that though many metals possess a high value of the spreading coefficient, there is a possibility of materially altering this condition by producing conditions analogous to the "contamination" mentioned above.

Another very interesting clew to a possible solution of this adhesion problem is presented in the orientation theory of surface structure. This was presented by Hardy and developed into a definite and experimentally founded theory by Harkins and Langmuir, independently.

In the first place, all solid material possesses an internal molecular structure which consists of an orderly and symmetrical arrangement of its molecules. This structure was first made apparent by the symmetrical distribution and orientation of the surfaces upon crystals.

Hardy states (21): The corpuscular theory of matter traces all material forces to the attraction or repulsion of foci of strain of two opposite types. All systems of these foci which have been considered would possess an unsymmetrical strain field, equipotential surfaces would not be disposed about the system in concentric shells. If the strain field of a molecule, that is, of a complex of these atomic systems, be unsymmetrical, the surface layer of fluids and solids which are close packed states of matter, must differ from the interior mass in the orientation of the axes of the field with respect to the normal to the surface, and so form a skin on the surface of a pure substance having all the molecules orientated in the same way instead of in random ways. The result would be the polarization of the surface and the surfaces of two different fluids would attract or repel one another according to the signs of their surfaces."

Langmuir (22) in his first paper on orientation advances another step: "In benzol itself the group molecules arrange themselves so that the benzol rings lie flat on the surface, since the flat sides of these rings are the less active portions of the molecules. The surface energy of benzol is about 65 ergs per square centimeter.

"If now an active group such as O H is substituted for one of the hydrogens in the benzol (forming phenol or carbolic acid), this group is drawn into the body of the liquid tilting the benzol rings up on edge and raising the surface energy to about 75 ergs per square centimeter, which corresponds to the activity of the perimeter of the benzol ring. Thus any active group strong enough to tilt the ring up on edge raises the surface energy to about 75. Two active groups side by side (ortho position) have no greater effect than one. But two active groups opposite one another (paraposition) cannot both go wholly below the surface so that the surface energy then becomes abnormally large (about 85 ergs in the case of paranitrophenol). The substitution of methyl or ethyl groups in the benzol ring lowers the surface energy except where an active group in an adjacent position draws these groups below the surface."

The following quotation is from Harkins, Davis and Clark (23): "The molecules in the surfaces of liquids seem to be orientated and in such a way that the least active or least polar groups are orientated towards the vapor phase. The general law for surfaces seems to be as follows: If we suppose the structure of the surface of a liquid to be at first the same as that of the interior of the liquid, then the actual surface is always formed by the orientation of the least active portion of the molecule towards the vapor phase, and at any surface or interface the change which occurs is such as to make the transition to the adjacent phase less abrupt. This last statement expresses a general law of which the absorption law is only a special case. If the molecules are mono-atomic and symmetrical, then the orientation will consist in a displacement of the electromagnetic fields of the atom. This molecular orientation sets up what is commonly called a 'double electrical layer' at the surfaces of liquids and also of solids."

It is obvious that this very remarkable theory presents a promising field for study and research in connection with the adhesion of soil to plow metals, for as above stated this surface skin formation is a well-known characteristic of metals and crystals, and if it is possible to alter materially the free surface energy and consequently the Wa, the draft of an implement would be affected accordingly. The possibilities of treating or allowing metal surfaces to give a low adhesive quality would seem sufficient to justify extended research, since tillage is one of the greatest consumers of power. Certainly it is unreasonable to expect a solution by modifying the soil.

High Moisture Ranges

Above a 10 per cent moisture content in sand, the film immediately grasped the slider and it was impossible to keep the slider dry, thus giving an increased pull with a consequent increase in the value of U'. This may be thought of as a decrease in the value of the Wc of the surface of the films, due to their greater diameter. When the film moisture became still more loosely held, there was a decrease in friction or pull due to the "lubricating" effect of this comparatively free moisture. This would indicate that in plowing soil of this moisture content a film adheres to the plow metal and the friction is transferred to within the liquid itself. With greater pressure the film moisture is changed to free moisture and flows rapidly to the surface so that the plow moves over surfaces lubricated with water. This is analogous to the action of skates on ice, the runner temporarily changing the ice to water by means of its pressure. This effect is shown by the following:

Effect of Pressure on U'

(Chilled iron on clay, 50 per cent; sand, 50 per cent)

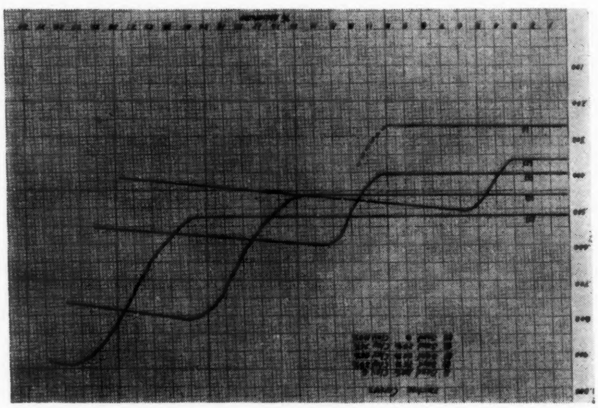
Wt.-gms.	Pull-lbs.	Normal-lbs.	Decreased Pull-lbs.	U'	Decrease of U'
1500	800	....	......	.533	....
3000	1400	1600	200	.466	.066
4500	1800	2400	600	.400	.133

The same effect is apparent in electro-end osmose when the current carries the moisture to the surface. To carry out the nomenclature previously suggested by Greenhill, we have called this "sliction". That draft can be materially reduced by the electric method has been demonstrated by the Rothamsted Experimental Station, England (24), but yet no generally applicable methods have been devised.

Synthetic Soils

With the mixtures of 75 per cent of sand and 25 per cent of clay, 50 per cent sand and 50 per cent clay, and 25 per cent sand and 75 per cent clay, practically the same conditions obtain as with pure sand, except that as the clay content increased, the stiction increased, coming earlier in the curve when the clay percentage was smaller and getting higher and later when the percentage of clay was higher. The lateness evidently is due to the fact that it takes a greater percentage of water to wet the clay to a given point of stickiness, and the height is due to a greater number of small films. The accompanying curves show what takes place when the slider is drawn over the different soils. Although it is a fact that these curves hold for the soils studied, it should be borne in mind that they are only exactly true for the specific metal surface studied. From tests with other metals it is believed, however, that they represent the general conditions that obtain in soils in that they show various phases of friction (as the term is commonly used in the industry). Moreover, the curves are in accord with what every one familiar with soils has observed, with the exception that they do not take into account organic matter which is common in all soils and is a great factor affecting moisture. It will be observed that all these curves are essentially alike from which it may be deduced that as far as particle size is concerned (and without doubt this is the most important factor in all soil mechanics), the frictional resistance of soil to a sliding metal follows well established laws, capable of mathematical expression, once the spreading coefficient (or its equivalent) is known for a given metal. The standard U. S. D. A. Bureau of Soils analysis would probably give a sufficiently accurate basis for such computation.

The length of the lower straight portion of each curve is roughly proportional to the tensions of the films, i. e., a high Wc, which prevents spreading and consequently adhesion; this is proportional to the small particles, largely colloidal. The magnitude of the rise is roughly of the same proportion. The exact slope of the rise in the curves given is somewhat uncertain, as at these critical moisture percentages, very slight variations caused wide fluctuations in the scale reading and the moisture was varied two per cent at a time. Once the films are extended to the point of sliction, i. e., when free moisture is present in the soil, the size of particle is of relatively small importance over the range studied. The lower straight part of the curves is considered to represent the normal coefficient of friction of the soil. This varies with the size of particle.



Curves showing what takes place when the slider is drawn over the different soils. Prof. Nichols makes the important deduction from these curves that "as far as particle size is concerned (and without doubt this is the most important factor in all soil mechanics), the frictional resistance of soil to a sliding metal follows well-established laws, capable of mathematical expression, once the spreading coefficient (or its equivalent) is known for a given metal"

These curves do not take soil structure into account, which is a very important factor affecting the bearing power at the lower moisture ranges and thus indirectly the friction. However, when the bearing power is greater than the pressure, which is a necessary condition for friction determination, this factor becomes negligible. At least all the variation which could be produced did not materially affect the results.

Since normal soil friction is between a metal surface and film moisture, the size of particle is of the greatest importance for it directly affects the surface tension of the film within any practical range of moisture for field operations. That the stiction is directly an effect of these small particles may be easily shown. For instance, a polished steel disk of 10 square inch area, weighing 200 grams, required a pull of 1800 grams to break it loose from a clay soil. With a soil colloid separated from the same clay by centrifuging it required a pull of 3630 grams.

Numerous investigators have found this to be the case. Hilgard (6) as far back as 1910 states "In any case the properties of plasticity and adhesiveness are restricted to the particles so fine that they fail to settle in 24 hours through a column of pure water 8 inches (200 m.) high, while some are so minute they will not settle for many months and even several years."

Summation

From the studies made it seems possible to lay down tentatively certain fundamental laws for sliding friction between a metal surface and the soil, remembering that these hold only between certain limits. This is a fact common to all laws of friction.

A. Friction Phase. In a dry soil when the value of S is negative and when the bearing power of a soil is less than the pressure, the coefficient of sliding friction (U')

- (a) Varies with the speed,
- (b) Is proportional to the pressure per unit area, and,
- (c) Varies with the smoothness of the surface and the materials of the surface.

B. Friction Phase. When the bearing power of a soil is greater than the pressure per unit area and the value of S is negative, i. e., the slider does not get wet.

- (a) The magnitude of the friction is proportional to the total pressure between the two surfaces;
- (b) The value of U' depends upon the roughness of the surfaces and the materials of the surfaces;
- (c) It is independent of the area of contact, and
- (d) It is independent of the speed of sliding.

C. Stiction Phase. When there is enough moisture present to cause the soil to adhere to the sliding surface (a positive value of S), but not enough to leave moisture brought to the surface, then U'

- (a) Varies with the speed;
- (b) Varies with area of contact;
- (c) Varies with the pressure per unit area;
- (d) Varies with the surface tension of the film moisture, i e.,
  - (1) It varies with the amount of colloidal matter present,
  - (2) It varies with the amount of water present, and
  - (3) It varies with the temperature and viscosity of soil solution, and
- (e) Varies with the surface and kind of metal.

D. Sliction Phase. Where there is enough moisture present to give lubricating effect, U' varies

(a) With the pressure per unit area,
(b) With the speed,
(c) With the amount of moisture and viscosity present, and
(d) With the nature of the surface and kind of material of which it is composed.

It will be seen that the coefficient of sliding friction is a dynamic and constantly varying factor rather than a fixed quantity and that in any soil it is affected by moisture content and particle size. The importance of these factors in practical plow design is obvious. In the "A" phase the shape that would give the lowest surface speed of soil over the metal surface and the lowest pressure per unit area of contact would give the least frictional resistance. Soils of this nature are usually worked with a steep moldboard plow, however, which is exactly the opposite to what frictional laws would seem to indicate is advisable. It is true that, with the horse, friction is not so important under these conditions, but with the advent of the tractor these same soil conditions render traction the limiting factor. Why should moldboards, which increase the friction and draft, be used when pulverization of these light sandy soils is comparatively unimportant?

The ordinary range of plowing is represented by the "A" and "B" phase, but the "B" phase would also seem to indicate the gentler slopes of the moldboard. However, as the structure here is the important factor which gives the bearing power, pulverization is more important and with the tractor, traction is a less critical factor. In some soils (push soils) "B" completely disappears, the value of S being positive, due probably to a low value of Wc in the formula S equals Wa minus Wc. The possibilities of a solution of this problem have been previously discussed but it should be noted that the importance of the S value is not limited to push soils, the limits of "C" and "B" being determined entirely by the S value of the metal. The sliction phase is of little importance in plowing because under these conditions a soil "puddles".

It should be borne in mind that this is a progress report especially prepared upon request. The question as to why soil sticks to a plow metal is simple enough, but one for which as yet no simple answer is available. As to what adhesion is, the only theory is advanced which could be found. It is logical and sufficiently well established to be taken as a basis for engineering research. While at first glance these theories seem complicated, there can be little doubt that the final answer to these heretofore unsolvable complications of the farm implement designer lies in their further unfolding, as our problem is one of the interrelations of surface energies between metals and soils. That the work of these investigators points to the possible solution should be of the greatest encouragement.

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Soil Colloids and Tillage

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(Continued from the March Issue)

Factors Affecting Flocculation

Apparently moisture is not the only factor having a broad influence on tillage, however. Any factors which promote a condition of flocculation in soils are as a rule considered to be favorable to tillage, since flocculation is usually directly opposed to cohesion and adhesion, and is a natural aid to the production of the generally desired crumb structure in soils. Such factors may be natural, as heat, dryness, or aeration, or they may consist of manuring and fertilizing or liming. Whether natural or artificial, however, they seem to exert an influence which is either favorable or unfavorable to the flocculation of the colloidal material according to the circumstances.

A most practical case in point includes studies at the Rothamsted experimental station in England on the effect of chalk on the cultivation of heavy soil. These showed that chalking not only permitted an increase in the speed of plowing but considerably reduced the draft. Studies at the Oklahoma experiment station showed that lime and manure greatly increased the bacterial activity and moisture capacity of upland soils of a hardpan nature, and greatly decreased the resistance to penetration of this soil in the field by a steel cone driven by a trip hammer.

However, studies at the New Jersey experiment stations on the modulus of rupture of soil as an index of its physical structure showed that the action of lime was distinctly differential, apparently depending upon the nature and type of the soil. In a clay soil for instance, the effect of liming was more or less promptly noticeable through a decrease in the modulus of rupture. On the other hand, in the case of a loam soil, the results did not indicate the same effect, the tendency being apparently in the opposite direction. This behavior of lime in different soils would seem to explain the anomalous effect of its activity in certain soils where apparently it is quite the opposite of that theoretically expected. Incidentally in tests with alkali soils it was also found that the modulus of rupture steadily decreased with the progressive neutralization of the alkalinity.

These results are most significant in that, while they indicate results from liming favorable to tillage in some soils, they also sound a warning against the indiscriminate use of lime for this purpose on all soils. Obviously a more intimate knowledge of the fundamental details of the influence of different forms of lime and other salts on the physical properties of soils is extremely important from the standpoint of tillage.

In this connection the conclusion has been reached by one agency in this country that the behavior of soils under the influence of salts agrees in some measure with the laws which are thought to govern the behavior of colloidal disperse systems to which salts have been added. Studies by the U. S. D. A. Bureau of Soils on the effect of the addition of small amounts of soluble salts on the physical properties and the structure of a soil showed that the colloid-like clay particles are affected most by soluble salts and in turn most affect the soil structure. German experiments showed that the hydroxyl ions of calcium and other hydroxides act upon the clay of soil, forming and flocculating col-

loid substances. This effect is greatest the first time clays and clay soils are subjected to such action and diminishes when the action is repeated until the clay particles lose the property of forming colloids. This may in a measure explain the diminishing effect of repeated liming on soil structure sometimes observed, especially where the hydrate is used.

Somewhat contrary to these findings, experiments in Holland showed that the flocculating effect of calcium hydroxide on clay suspensions is due principally to the calcium ion rather than to the hydroxyl ion. It was found that both sodium hydroxide and sodium carbonate solutions had a flocculating effect on clay suspensions only in strong concentrations and when very dilute had a stabilizing effect, while calcium hydroxide had a flocculating effect when both dilute and concentrated. It thus seems evident that the flocculating effects of calcium hydroxide and sodium hydroxide cannot be attributed entirely to the same causes. This appears also to correspond quite closely to conditions observed in actual practice and may explain several tillage phenomena where soils are heavily fertilized.

Going more intimately into this matter, studies in Germany on the formation of crumb structure in tillage indicated that unfavorable conditions of the soil structure are frequently due to hydroxyl ions but that positively charged calcium ions may have an especially favorable action on the production of crumb structure. Hydroxyl ions were found to be strongly absorbed by soil and thereby became electrically charged. In combination with the weakly flocculating alkali ions, such as potassium, sodium, and ammonium, the soil structure was injured. However, when the more strongly flocculating ions such as calcium were present in sufficient quantities, the presence of a great quantity of hydroxyl ions increased flocculation and crumb structure formation. Further German experiments confirmed the finding that the dispersing action of hydroxyl ions in soil depends much more upon the nature of the cations predominating in the soil solution than upon their own activity in this respect. The unfavorable influence of large additions of caustic lime, frequently observed, especially on heavy soils deficient in lime, was found to be due to the fact that bacterial action and carbon dioxide formation are depressed by the caustic lime. A low calcium hydroxide concentration in the soil solution follows, resulting in injury to the soil structure. These results seem to show quite definitely that calcium hydrate favors tillage conditions in some soils, especially in clay soils, but would seem to sound a warning against the indiscriminate use not only of limes in general but of caustic lime in particular. They also emphasize the importance of an even more intimate knowledge of the reasons why this influence of lime and fertilizer salts is exerted on the physical properties of different soils which govern tillage.

Further light is thrown on this matter by studies conducted at the University of Leeds in England on the flocculation of neutral and alkaline suspensions of clay, silt, and whole soil by calcium salts. The results showed that silt, like most insoluble substances, when suspended in water, is most easily flocculated by calcium salts if the suspension is neutral. The addition of alkali stabilizes the solution and renders flocculation more difficult. Soil clay behaves in an opposite manner and is precipitated from alkaline suspensions more readily than from neutral suspensions, resembling silicic acid and other emulsoid colloids in this respect. This would suggest that the clay particles are protected by such colloids and thus behave as an emulsoid. If this is true the action of lime on soil is apparently in accordance with the principles of colloid chemistry. In this connection further experimental evidence was advanced to support the view that clay acts as an emulsoid and protects the larger soil particles, which by themselves are suspensoids and as such are distinctly unfavorable to crumb important bearing on tillage and show most strikingly how the clay content of soils under proper circumstances and structure formation. These results obviously have a most treatments may be almost the governing factor in the production of desired tillage results. On the basis of these findings the soil aggregates may be conceived as having large nuclei surrounded by particles which become smaller from the center outward, the clay ultimately imposing its emulsoid nature on the whole aggregate and on the whole soil in normal cases. Therefore it stands to reason that the fine silt soils are not flocculated by calcium hydroxide on account of the inefficiency of their relatively small content of emulsoid clay in protecting the large suspensoid surface exposed by the fine silt. The significance of these results with reference to the production of proper tillage results in silty soils tending to become alkaline is also plainly evident.

Still further light is thrown on the relation of soil treatment to tilth by German experiments which showed that most soil gels are reversible and most soil colloids are negatively charged, which naturally explains their power for absorbing the positively charged bases of basic salts. Such absorption was found to result in gel formation and better soil structure. The absence of electrolytes or the presence of physiologically basic salts such as sodium nitrate were found to cause the formation of sols which resulted in compact, poorly aerated soil structure. In such cases fall plowing is suggested, as it allows the winter frost to form gels in the soil, thus loosening the structure. Heat and dryness were also found to coagulate the soil colloids and improve the structure but too heavy rains formed sols of the reversible gels, and also by washing out the salts, or in other words by plain leaching, caused a return of the compact, badly aerated structure. The beneficial effect of lime salts on soil structure was found to be due to the higher gel-forming power of bases of higher valence and that the more the effect of the positive ion exceeded that of the negative ion the more beneficial was the effect on the soil structure. The beneficial effect on the soil structure of stall and green manure was found to be due to the addition of new colloids which not only form gels but dissolve lime. The significance of these results to tillage is so obvious as to require no comment.

Freezing

Freezing is known to have an influence on the physical properties of soil under certain conditions and may therefore frequently have a marked bearing upon the production of desired tillage results as well as upon the mechanical difficulties of tillage. In this connection German experiments showed that when crumbly soil was exposed to freezing conditions, no volume changes occurred and apparently the ice crystals formed mainly in the void spaces. The formation of so-called frost crumb structure was found to occur mainly on the surface of soil and to penetrate only so deeply as the frost itself penetrated. However, the condition of frost crumb structure was found to approach the ideal cultural condition of soil. Further studies showed that where loam or clay soils were pulverized in a dry condition they did not readily resume their firm shape, and that scarified clay soils were completely changed in character. However, the smallest particles comprising the frost crumb structure were found to be very densely stratified and similar to moistened and compressed loam or clay. These particles are therefore concluded to be the nucleus of the structure of loam soils. Further studies in Germany showed that no variation in the surface area of six different surface soils due to freezing could be detected, and it was concluded that as the effect of each successive freezing on surface soil steadily decreased the actual effect of frost on the soil surface approached a maximum in approximately an asymptotic manner. Apparently the mass of irreversible colloids of surface soils is so reduced by freezing and drying that the hygroscopicity values of the remaining irreversible colloids are fully covered by those of other soil constituents. These results apparently indicate that frost action may, in some soils, favorably supplement tillage. They raise the question as to whether frost action should precede or follow tillage to be most favorable and introduce a consideration in the production of desired tillage results which may be worthy of investigation in some localities.

Hardpan and Plowsole

Soil formation by weathering is now considered by many to be based on colloid chemistry, especially the formation of hardpan and plowsole. These soil types are of considerable importance from the standpoint of tillage in certain local-

ities, and a knowledge of why and how they are formed and under what conditions they may be corrected or prevented may be important. Studies in England in this connection showed that the separation of removable material into a definite layer as in pan formation, while an exceptional feature, is always associated more or less with the existence of an acid humus layer.

Studies conducted by the U. S. Department of Agriculture showed that plowsole is a hard soil layer which usually forms immediately under the soil mulch in cultivated citrus groves, for instance. After being broken up with a subsoiler it forms again when cultivation is resumed. Mechanical packing is not necessary for its formation. Plowsole was found to contain a markedly higher percentage of inorganic colloid suspension than the soil mulch, and usually a higher percentage than the subsoil. The colloids were found to move with the capillary soil moisture. Native uncultivated soils contained appreciably less colloid suspension than did similar soils which had been under cultivation for a number of years. The decomposition of 3 per cent of organic matter in the soil decreased the percentage of colloid suspension in some cases. Barley decreased the percentage of colloid suspension more than did alfalfa or manure. Ground lime rock appreciably decreased the percentage of inorganic colloid suspension in the soil when no organic matter was added. However, when organic matter was added the flocculating effect of lime was appreciably diminished, especially in clay soil. Powdered sulfur and gypsum markedly decreased the colloid suspension content of soil, and organic matter had no appreciable effect in counteracting the flocculating effect of these substances. Sodium nitrate markedly increased the colloid suspension content of soil, but the addition of organic matter appreciably decreased the deflocculating effect of this fertilizer. The percentage of iron and aluminum in colloid suspensions from soils which readily formed hard plowsole was higher than in colloid suspensions from soils which did not. The percentage of iron and aluminum in the colloid suspension from a soil was thus found to be directly correlated with the readiness with which the soil formed a plowsole.

The formation of hardpan and plowsole is thus quite definitely tied up with the colloidal phenomena of the soil, with special reference to the iron and aluminum content of the colloid suspension, which is distinctly unfavorable to soil structure. These results also serve to indicate the lines along which further study must be undertaken of means of preventing plowsole formation or of correcting it and would seem to show that organic manures, lime, and other amendments and fertilizers cannot be used indiscriminately in that connection.

Conclusion

This review of experimental data on the chemico-physics of soils, while incomplete, is intended primarily to show some of the more important lines along which the colloidal influences of soils may be exerted with respect to tillage. Incidentally some of the methods for artificial modification of the properties of soil colloids in a manner favorable to tillage processes are outlined, and the importance of recognizing and taking advantage of natural influences favorable to tillage is emphasized. One of the most striking indications of these data is that, with reference to soil colloids and tillage, things are not always what they seem. This is true especially with reference to treatments such as liming and manuring to improve tillage conditions. It seems evident, however, that colloids and colloid-like materials in soils play a quite important part in the production of desired tillage results, in the development of machinery therefor, and in determining the power required.

The opportunity for the development of research in tillage and tillage machines along more fundamental lines thus seems to lie in a closer cooperation with the soils specialist. Obviously the past work in tillage has not given proper consideration to the chemico-physical properties of soils. Just as obviously, owing to the incompleteness of the data available, the work in chemico-physics of soils has not been aimed primarily at the fundamental development of tillage practices. It seems high time therefore for agricultural engineers and soils specialists to get together on a study of the development of tillage and tillage machines along some of the fundamental lines mentioned.

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Book Review

"Dairy Engineering," by John T. Bowen, B. S., Engineer, Bureau of Dairying, U. S. Department of Agriculture, is the latest addition to the Wiley agricultural engineering series edited by J. B. Davidson, professor of agricultural engineering at Iowa State College. The book is intended primarily for those engaged in the production and handling of milk and in the manufacture of milk products and in the selection, installation, operation, care and management of the necessary machinery. It is also intended for use as a text-book in dairying. The following chapter titles give an idea of the contents of the book: Definitions and units; steam and steam boilers; boiler settings; boiler fittings and accessories; chimneys; combustion-firing; the steam engine; steam piping and accessories; exhaust steam and its uses; sources of heat losses in small steam plants; the internal-combustion engine; transmission of power; the compression refrigeration system; methods of utilizing refrigeration; installation; direct-current motors; alternating-current motors; and temperature measurements and control. The book contains 521 pages of text matter and 163 illustrations. It is published by John Wiley & Sons, Inc., New York City, and the price is $3.75 net.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in rural engineering, Office of Experiment Stations, U. S. Department of Agriculture

Artificial Haymaking. (Implement and Machinery Review, London, 50 (1924), No. 594, pp. 654, 655, fig. 1; also in Engineering, London, 108 (1924), No. 3068, pp. 554, 555, figs. 2.) A brief account is given of studies conducted by the Institute of Agricultural Engineering Research of Oxford University, England, on the artificial drying and curing of hay. Investigations on the consolidation of the stack, porosity of the material in relation to penetrability, design of the chamber around which the stack is built, and the design of the fan resulted in the development of a central chamber that permits of equal penetration of the air in the stack.

It has been found that the requirements of proper drying are met best by using a cone-shaped structure in a circular stack. The slope of the side of the structure is based on turbulence, consolidation of the crop, and the porosity at different levels. A special air preheating arrangement is used in which the air is drawn by a fan over several hot spots or spiral heat conductors heated by paraffin fires under pressure. This air passes out of the heating chamber through a duct into the central chamber in the stack from whence it passes uniformly to all parts of the mass. It has been found advisable to restrict the size of the stacks to from 10 to 25 tons, and to build them regularly to avoid uneven distribution of the air. The hay is stacked immediately after cutting, and blowing with preheated air is started as soon as the stack is completely made. It has been found that under ordinary circumstances a stack containing excess moisture will gradually heat until a temperature of 120 degrees F. is reached. Fermentation then sets in and causes a rapid rise to about 150 degrees, which is sufficient to kill many of the bacteria responsible for the heating. At such a stage, however, there is danger of another rapid rise due to ordinary chemical oxidation. In the drying process there is no need for the temperature of the stack to rise above 100 degrees, and fermentation is completely arrested.

The hay made by this process has been of a green appearance and has a pleasant smell and good taste. On the other hand, hay made in the ordinary way has some of its chemical constituents destroyed by the sun and prolonged exposure. Nutritive elements of the artificially cured hay are also said to be preserved to a greater extent. It is noted that the artificial method of curing is also being extended to corn drying.

Fuel Saving Devices and Treatments for Internal Combustion Engines. (Nebraska Station Report, Lincoln, 1923, p. 8.) Tests of a number of representative fuel-treating materials showed that the same results can be secured by proper adjustment of the carburetor without fuel savers as when these are used. Gasoline improvers did not in general give a marked saving in fuel nor increase the mileage per gallon. When any improvement was noted, it was so slight that it did not pay for the added cost of the improver.

Plow Bolts. (U. S. Dept. Commerce, Office of Secretary, Elimination of Waste Series, Washington, D. C., pp. 9, figs. 4.) This circular presents the report of a general conference of the farm equipment manufacturing industry and a simplified list of plow bolts proposed on that occasion by the National Association of Farm Equipment Manufacturers.

Highway Transportation Costs, T. R. Agg and H. S. Carter. (Iowa Engineering Experiment Station, Ames, Bulletin 69 (1924), pp. 32, figs. 6.) This publication presents a discussion of highway transportation costs, which is an outgrowth of a rather prolonged study of the various factors affecting vehicle operating cost, such as rolling resistance and the relation between road types, fuel consumption, and general operating costs of vehicles, and which has been carried out for the most part by the engineering experiment station of Iowa State College in cooperation with the U. S. D. A. Bureau of Public Roads. The discussion of the economic principles involved in providing highway transportation at the minimum cost is intended to show the nature of the problems involved and concerns itself with both vehicle and highway costs.

Tests on the Hydraulics and Pneumatics of House Plumbing, H. E. Babbitt, (Illinois University Engineering Experiment Station Urbana, 143 (1924), pp. 80, figs. 31.) Studies to obtain information concerning the positive and negative pressures found in soil stacks, waste pipes, traps, and vent pipes, and also concerning the limitations of rates of discharge and the capacities of waste pipes and soil stacks are reported. Various diameters, lengths, and arrangements of pipes, traps, and vents were tested.

The maximum change of the water in a trap resulting from the application of pressure was found to be approximately the same for all diameters of traps, provided they are sufficiently large to render the effect of friction in retarding the movement of water negligible. The minimum diameter of trap to satisfy this condition seemed to be about one inch. This is taken to indicate that for practical purposes in plumbing design the change of level of the water in traps will be the same under the same application of pressure, regardless of the depth of water in the trap.

The withdrawal of water from a trap was found not to weaken its resistance to the passage of air, provided the volume of water remaining in the trap was sufficient to fill the connection between the two legs and to form a vertical column of a height equal to the depth of seal in that leg of the trap in which the water rises. The resistance of a trap to the passage of air through it was found to vary directly with the depth of the seal. It is concluded that for safety in plumbing design it should be assumed that a water closet, other than the automatic valve type, may discharge at the rate of 50 gallons per minute for seven seconds.

With unvented traps the pressure was found to vary as the five-halves power of the rate of discharge down the soil stack. With vented traps the pressure varied as some constant power of the rate of discharge, depending upon the type and capacity of the vent, and varying between about one-third for very complete venting and five-halves for no vent. The positive pressure in unvented traps was found to vary as the five-halves power of the height of fall of the water to the point of observation. Neither positive nor negative pressure were produced above the point of entrance of water to the soil stack. The negative pressure was found to be dependent both upon the vertical distance the water falls to the point where the negative pressure is measured and upon the vertical fall below this point. The greatest positive pressure is greater than the greatest negative pressure anywhere in a soil stack.

The maximum rate at which water will flow down a 4-inch soil stack without creating uncontrollable pressures in a plumbing system was found to be high, and a 2-inch pipe is considered to be unsuitable for use as a stack. The rates at which one horizontal waste pipe of the same diameter as the soil stack will discharge water into a soil stack through a sanitary T without backing up in the waste pipe were found to be, for a 2-inch soil stack 25 gallons per minute for seven seconds, for a 3-inch soil stack 50 gallons, and for a 4-inch soil stack 100 gallons.

The submergence of the house drain resulted in a material increase in the pressures created in a plumbing system. Since the use of a house trap, either vented or unvented, at the end of the house drain increases the pressures throughout the plumbing systems, it is concluded that such a trap should not be used. Closures of the top of the soil stack or of vent pipes were found to result in such increases of pressure as to endanger the seals in traps.

The Effect of Haul on the Cost of Earthwork, J. L. Harrison. (U. S. Department of Agriculture, Public Roads, Washington, D. C. 5 (1924), No. 7, pp. 14-17, figs. 4.) The results of studies are summarized indicating that there is no means of handling earth which eliminates the factor of distance moved as a dominant element in cost. It was found that at certain hauls a wheeler will move earth more cheaply than a fresno, and for the longer hauls (over 300 feet) it appears probable that the elevator grader moves earth somewhat more cheaply than either of the other forms of equipment. However, no form of equipment has been found in common use which enables contractors to disregard distance as a primary consideration in the cost of moving subgrade materials.

Relative Effects of Some Nitrogen Compounds Upon Detonation in Engines, T. A. Boyd. (Industrial and Engineering Chemistry, Washington, D. C. 16 (1924), No. 9, pp. 893-895, figs. 3.) Studies are reported which show that nitrogen in some of its compounds exerts a greater influence upon the character of combustion in internal-combustion engines than any other element of small atomic number. The action of nitrogen is influenced in a large way by elements of radicals attached to it. Thus in some of its compounds it is quite effective for suppressing detonation, in some it is almost neutral, and in some it exerts the remarkable effect of reducing detonation. For example, detonation is suppressed by analin, it is affected very little by pyridin, and it is induced or increased by propyl nitrate.

The studies showed that in general the nitrogen compounds which are most effective for suppressing detonation are the primary and the secondary amines. Of these the aryl amines or those that contain at least one aryl group have much the larger influence for eliminating detonation from internal-combustion engines.

Drying by Means of Air and Steam, E. Hausbrand. (London: Scott, Greenwood & Son, 1924, 3. rev. Eng. Ed., pp. VIII+77, pls. 2, figs. 7.) This book, translated from the German by A. C. Wright, presents mathematical formulas and tabular data for calculating the dimension of apparatus, for drying wet materials by means of air, and for determining the consumption of air and heat in such drying apparatus. Chapters are included on calculation of the maximum weight of saturated aqueous vapor which can be contained in one kilogram of air at different pressures and temperatures; calculation of the necessary weight and volume of air of the least expenditure of heat, for drying apparatus with heated air, at atmospheric pressure; drying apparatus in which in the

drying chamber a pressure higher or lower that that of the atmosphere is artificially maintained; drying by means of superheated steam without air; and heating surface, velocity of the air current, dimensions of the drying room, surface of the drying material, and losses of heat. An appendix of metric conversion diagrams is also included.

Home Conveniences, F. W. Ives. (New York and London: Harper & Bros., 1924, XI+219, figs. 74.) This is one of Harper's handbooks, edited by W. C. O'Kane. Its purpose is briefly to set forth some of the things that make for comfort about the home and to aid the householder in the selection of appliances. While of an extremely popular nature, it is a striking example of the results of extensive fundamental work in agricultural engineering in which it is known that the late author was long engaged. It contains chapters on heating appliances, ventilation, cooking appliances, home laundry equipment, plumbing fixtures and accessories, disposal of waste, refrigeration for the household, cupboards and closets, cleaning devices, handy household devices, labor-saving kitchen devices, handy repairing conveniences, the electric motor and its application, the small internal-combustion motor and its application, lighting and light plants, the septic tank, methods of getting water into the house, and suggestions for reading.

Plowing Without Turning the Furrow, (In Austria), H. Kallbrunner. (International Review of Science and Practice in Agriculture [Rome], new series, 1 (1923), No. 3, pp. 587-594, pl. 1.) The method in vogue in Austria of plowing without turning the furrow is described and illustrated, and some of the advantages claimed for this process are enumerated. The method is based on the principle that it is necessary to avoid the making of clods, which are extremely difficult to break up. The best implement for this operation is said to be an ordinary plow from which the moldboard for turning the furrow has been removed. As a rule, an attempt is made to break up the soil to as great a depth as possible. In the spring, before seeding, cultivators alone are used, and no attempt is made to break up the subsoil completely. The use of wide, light harrows is also recommended. Practical experiments have shown that by breaking up the soil twice in this manner instead of once has resulted in a saving of labor of from 30 to 40 per cent.

The Properties and Uses of Wood, A. Koehler, New York and London: McGraw-Hill Book Co., Inc., 1924, pp. XIV—354, figs. 129.) In this contribution from the University of Wisconsin and the U. S. D. A. Forest Products Laboratory an attempt is made to present in a nontechnical manner the more important facts concerning the properties of wood and how these properties affect its utilization. Chapters are included on the structure of wood, the physical properties of wood, the mechanical properties or strength of wood, factors affecting the strength of wooden members, chemical properties of wood and their practical application, air seasoning of wood, kiln-drying, deterioration of wood, protection of wood against decay and fire, principal factors governing the use of wood, kinds and quantity of wood used for various purposes, measurements of timber products, and commercial grading and standard sizes of lumber.

Factors Influencing the Binding Power of Soil Colloids, H. E. Middleton. Journal of Agricultural Research [U. S.], Washington, D. C. 28 (1924), No. 6, pp. 499-513, figs. 6). Studies conducted by the U. S. D. A. Bureau of Soils on the factors influencing the binding power of colloids and the relation of the compressive strength of soil to the amount of collodial material present therein are reported.

A method was deduced for testing the binding power of soil colloids by determining the breaking strength of briquets molded from soils under definitely established conditions.

The factors influencing the breaking strength of a briquet were found to be (1) the amount of moisture present at the time of molding, (2) the treatment of the material before molding the briquet, (3) the pressure applied, and (4) the manner of drying. Some of the factors found to affect the binding power of soil colloids are (1) the amount of colloid present, (2) the size and grading of the noncolloidial material, (3) the kind of colloid, and (4) the dispersion of the colloid.

A general relation between the load per gram of soil, L, and the amount of colloid in the soil in per cent, C, was deduced and given expression in the formula, $L=.42\ C1.24$.

Tetralin, F. Nathan. (Fuel in Science and Practice, London, 3 (1924), No. 10, pp. 346-349.) Data on the history, manufacture, and use of tetralin for fuel in internal-combustion engines are presented. Tetralin is a colorless, stable hydrocarbon, and is considered to be a liquid fuel of considerable value. Owing to its high boiling point it can not be used undiluted as a motor fuel, but it has been found very suitable for that purpose when mixed with gasoline, benzol, or alcohol.

Comprehensive tests conducted at the Berlin Technical High School have shown that a mixture of equal parts of tetralin and ordinary gasoline gives the most satisfactory results, which are approximately equal to those obtained with benzol. Tetralibenzol is a mixture of benzol, alcohol, and tetralin, and is called "Reichskraftstoff" in Germany. This fuel has a calorific value of 8,350 calories. It produces no carbon deposit and has, on the other hand, been found capable of thoroughly dissolving such deposits, which are removed in a few days by the escaping gas.

Tests conducted in England at the Government Fuel Research Station showed that mixtures of tetralin and gasoline containing less than 50 per cent of tetralin are apparently quite suitable for use in ordinary four-cylinder automotive engines without any special adjustments. In every case it was found that mixtures of tetralin and gasoline are not so good as gasoline alone, either in flexibility of running, maximum power obtained, or thermal efficiency, but the inferiority is not sufficiently marked to preclude the use of tetralin, especially if it is slightly cheaper than gasoline. There were indications that a higher compression ratio may be used with mixtures of tetralin and gasoline than with gasoline alone. When the mixture of gasoline and tetralin contained more than 50 per cent of tetralin, the engine could be operated but was much less flexible and the power and efficiency were decreased considerably. It was found in general that as the proportion of tetralin in the fuel increases the faults associated with incomplete combustion also increase.

Wind Power for Farm Electric Plants, F. J. Pancratz. (Mechanical Engineering [New York], 46 (1924), No. 11, pp. 675-682, figs. 10.) A rather technical discussion is presented on test data on a fifteen-foot wheel, losses due to air drag, the best size of wheel for farm electric light plants, and a combination plant for generating electric power and pumping.

The data as a whole indicate that the characteristics of a windmill are not favorable for large units. A 20-foot wheel is about the largest size that can be used and give satisfactory results for generating electric power. The smaller sizes of wheel are considered to offer a cheap and reliable means of supplying the average farmer or isolated places with the necessary electric power and water, and the first cost, cost of operating, and depreciation are said to compare very favorably with those of gasoline lighting plants.

Reinforcing and the Subgrade as Factors in the Design of Concrete pavements, J. T. Pauls. (U. S. Department of Agriculture, Public Roads, Washington, D. C. 5 (1924), No. 8, pp. 1-9, figs. 5). Two and a half years' service studies of an experimental road on the relation between the cracking of concrete roads and the character of the subgrade and steel reinforcing are reported.

The results showed that subgrade materials with a large percentage of clay not only attain a high moisture content during the wet season but also during the dry season, and that subgrades having a large percentage of sand do not attain a high moisture content but have a high capillarity. Subgrades composed largely of clay swell and contract as moisture is added or taken away. The conclusion is drawn that subgrades that show as much as a 10 per cent change in volume by laboratory tests should be covered with a layer of coarse granular material, and a pavement laid on a subgrade of this character should have a longitudinal joint at the center.

It was found that plain concrete slabs will crack transversely because of temperature and moisture changes at intervals of from 40 to 60 feet. Smooth subgrade surfaces increase the distances between cracks, but the thickness of the concrete does not affect the spacing of the contraction cracks.

Pavements reinforced longitudinally will develop transverse contraction cracks, the number, spacing, and size of which are controlled by a number of factors. If the steel reinforcing is not continuous but is separated by joints, it is to be expected that no cracks will form less than 30 feet from any joint, and by a suitable relation of the percentage of steel to the length over which the steel is made continuous the distance may be increased to 60 feet. If the spacing of the joints is less than twice the distance in which a crack would form, contraction cracking may be entirely prevented. With a high percentage of continuous steel, relatively fine, closely spaced cracks may be looked for; with a low percentage breaks in the steel may be expected to permit wider cracks to form at considerable intervals. Mesh reinforcing was found to be likely to break at intervals and permit cracking.

Attention is drawn to the possible danger of the use of too high a percentage of longitudinal steel, since under such conditions numerous fine transverse cracks will develop making it possible that the narrow transverse beams thus formed will crack under traffic.

It was further found that the practice of omitting contraction joints in pavements reinforced longitudinally is questionable. Apparently the design should provide for contraction joints from 50 to 100 feet apart. The results as a whole are taken to indicate conclusively the great importance of subgrade investigations in connection with the design of pavements.

Motorized Soil Cultivation, B. Sievers. (Motorische Bodenbearbeitung. Neudamm, Germany; J. Neumann, 1924, pp. 99—[3].) This treatise deals with the practical phases of the subject, with particular reference to the requirements of German agriculture. It contains a discussion of the scientific bases of soil cultivation, and describes different cultivation methods. Reasons for the selection of different motorized plowing systems are enumerated, and the practical features of motorized cultivation are outlined in some detail.

Physical Properties of Materials—I Strengths and Related Properties of Metals and Wood. (U. S. Department of Commerce, Bureau of Standards Circular, Washington, D. C. 101, 2 ed. (1924), pp. 204, pl. 1, figs. 60). This is the second edition of this publication. It contains the values for tensile, compressive, and shearing strengths; ductility; modulus of elasticity; and other related properties of pure metals and their alloys and of wood. In addition to these the properties of metals at elevated temperatures, and fatigue and impact properties, and the effect of heat treatment and cold working are also given. Other properties and uses of less commonly used metals are described briefly. Graphic representation is used in many cases to show the change of the properties of a material with changing conditions.

News Section

New Plan for Annual Meeting

REAL progress is being made in the plans for the nineteenth annual meeting of the American Society of Agricultural Engineers to be held at Madison, Wisconsin, June 22, 23, 24, and 25, 1925. Elaborate preparations are being made by the Committee on Local Arrangements, which assures that the comfort and enjoyment of those in attendance are being given every consideration.

The first day will be devoted exclusively to demonstrations, excursions, round table discussions, committee meetings, etc. This will include among other things a three-hour inspection of the Forest Products Laboratory of the U. S. Department of Agriculture at Madison and a meeting of the heads of agricultural engineering departments of the state colleges in the evening.

The second day, June 23, will be devoted exclusively to meetings of the professional divisions. Simultaneous programs of the Farm Power and Machinery, Reclamation, and Farm Structures Divisions will extend throughout the day. The annual business meeting will be held on the evening of that day.

The plan followed last year was to hold a general session in the middle of the day, at which all those in attendance at the meeting were given an opportunity to listen to an address by someone of national prominence. This year the entire third day of the meeting, June 24, will be devoted to a general program, the purpose of which will be to have presented papers on general subjects on all phases of agricultural engineering. A very interesting program is being planned.

The annual banquet of the Society will be held on the evening of June 24, following the general program.

The entire fourth day of the meeting, June 25, will be devoted to the program of the College Division, which will feature papers and reports on various phases of college work, including resident teaching, research, and extension.

Of special interest to members of the Society, particularly those interested in rural electrification, is the rural electrification conference to be held under the auspices of the Committee on the Relation of Electricity to Agriculture on Friday and Saturday, June 26 and 27, at Madison.

American Forest Week

AMERICAN Forest Week, which President Coolidge has officially proclaimed for April 27 to May 3, is to bring before all citizens of the country the full facts concerning America's forest problems. "The United States Forest Service earnestly hopes that the subject will be treated intelligently and thoroughly," says Col. W. B. Greeley, chief of the Service. "A flash in the pan will not suffice to solve the problems of America's future timber supply. This nation heretofore has lacked a definite forest policy around which all interests could rally and fight the battle shoulder to shoulder. The Clarke-McNary Act has given us this policy after many years of striving."

The Clarke-McNary Forestry Act, passed by Congress in June 1924, represents a definite and important milestone in America's national forestry policy. The law declares for a policy in which the federal government, state governments, private landowners, and the lumber industry can all take part. Briefly the Clarke-McNary Act recognizes the need and place of private forestry in the United States, along with and supplementing public forest ownership.

The law, among other things, authorizes the U. S. D. A. Forest Service to cooperate with the states in devising and recommending efficient systems of fire protection to the end that a nationwide plan of forest protection may be developed. Federal funds, when matched with state and private funds, will aid in carrying out these protective systems.

The Clarke-McNary Act also aids in the distribution of forest trees for planting by private owners. At the present time all agencies in the United States are planting less than 40,000 acres of young forest annually, whereas Japan, for example, plants more than 350,000 acres per year.

The second line of attack in accomplishing the purpose of this forestry law is to extend the national forest system in areas where special public interests are involved, such as the protection of the watersheds of navigable rivers, or where the natural difficulties attending reforestation make it impracticable or remote as a private undertaking. In the words of Col. Greeley, "The forest interests of the country as well as those interests which depend upon the various products of the forest, should actively participate in the nationwide movement to get a national forest policy in effective operation."

Agricultural engineers have a real interest in reforestation and forest protection, and it is urged that members of the American Society of Agricultural Engineers exert their best influence in aiding the fulfillment of the purpose behind the American Forest Week.

More Money for Agricultural Research

A BILL of special interest to agricultural engineers which recently passed Congress, and which has received the signature of the President, is the Purnell Bill providing for an increase of federal funds available for state agricultural experiment stations research in addition to the amount now received by such stations. The Purnell Bill makes available on July 1 the sum of $20,000.00 additional for each agricultural experiment station, with a $10,000.00 increase annually for four years until the total amount available to each station each year has reached $60,000.00. At the same time the bill was passed a letter was addressed by the Secretary of the Society to the heads of agricultural-engineering departments at the various state colleges urging that prompt action be taken in the matter of planning a program of real research in agricultural engineering so that they would be prepared to get the proportion of the additional funds which this important branch of agriculture merits.

This offers an opportunity for agricultural engineers to get in on the ground floor on a new research program and they should take advantage of it by working out a well-balanced research program and getting it approved by the director of the experiment stations and the deans of their colleges.

Iowa Student Branch Holds Dinner

THE student branch of the American Society of Agricultural Engineers at Iowa State College on February 4 held a dinner in honor of Finley P. Mount, president of the National Association of Farm Equipment Manufacturers. On that date Mr. Mount delivered an address to a mass meeting of students and farmers attending Iowa's Farm and Home Week. The subject of his address was "The Manufacturer's Message to the Iowa Farmer." The officers of the Iowa Student Branch are Wilbur M. Hurst, president, and Paul V. Morrissey, secretary.

Fire At Clemson Agricultural College

THE Clemson Agricultural College, the state land grant agricultural college at Clemson, South Carolina, suffered a very serious loss when the Agricultural Hall of that institution was completely destroyed by fire, April 2. Very little contents of the building were saved.

The building housed practically all of the agricultural departments of the institution, including the agricultural experiment station. The equipment used in the agricultural engineering work at the institution, except heavy machinery, was also destroyed.

J. T. McAlister, associate professor of farm machinery at Clemson Agricultural College, reports that everything he had accumulated in the way of a library, notes, bulletins, tracings, and blueprints, etc., were completely destroyed in the fire. He is having to start all over again in the accumulation of material.

Prof. McAlister has requested that the editor of AGRICULTURAL ENGINEERING make a special request to agricultural engineering departments at the land grant colleges that they send him copies of bulletins from their experiment stations and extension service, and any other agricultural engineering publications or material which they have available, and also anything in the way of teaching aids, note books, and laboratory guides. Any material that other institutions can furnish Prof. McAlister will be very much appreciated.

Personal

A. L. Burras during the past few months has been engaged as a surveyor for the Florida Public Service Company, Orlando, Florida, which is engaged in dividing up some of the enormous acreages of cut-over land into farms of various sizes.

F. L. Fairbanks, department of rural engineering, New York State College of Agriculture, is the author of a bulletin entitled "Artificial Illumination of Poultry Houses for Winter Egg Production." It is an excellent contribution to the subject.

H. W. Riley, professor of agricultural engineering, New York State College of Agriculture, recently presented a paper entitled "Electricity in New York Agriculture," at the annual meeting of the commercial section of the Empire State Gas and Electric Association, which made the picture of rural electrification in its present stage but does not undertake to look forward into its future.

P. Arthur Tanner has been appointed sales manager of Cushman Motor Works, Lincoln, Nebraska.

New A. S. A. E. Members

Frank R. Brownlee, thresher engineer and service manager, Minneapolis Steel & Machinery Company, Minneapolis, Minnesota.

Arthur W. Farrall, assistant in dairy industry, University of California, Davis, California.

Millard A. Klein, consulting agriculturist, 517 First National Bank Bldg., Stockton, California.

J. B. Trotman, manager, commercial pump sales, The Goulds Manufacturing Company, Seneca Falls, New York.

Floyd S. Wheeler, general engineer, Westinghouse Electric & Manufacturing Company, East Pittsburg, Pennsylvania.

TRANSFER OF GRADE

Wendell P. Miller, consulting agricultural engineer, 247 East Broad Street, Columbus, Ohio. (From Junior Member to Member.)

John Laroy Saunders, junior engineer, U. S. Geological Survey, Water Resources Branch, Austin, Texas. (From Student to Associate Member.)

Applicants for Membership

The following is a list of applicants for membership received since the publication of the March issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for the consideration of the Council prior to election.

Arthur Richard Klaffy, Huntington, Long Island, New York.

Ludwig Holland Letz, mechanical engineer, Letz Manufacturing Company, Crown Point, Indiana.

Walter Wesley McLaughlin, irrigation engineer, Box 180, Berkeley, Calif.

Howard S. Reed, president, Reed & Company, Los Angeles, California.

H. F. Reiss, vice-president, J. B. Colt Company, 30 E. 42nd Street, New York City.

Otto B. Stitchter, manager, Louden Machinery Company, Albany, New York.

Archibald Williams, branch manager, J. B. Colt Company, 31 Exchange Street, Rochester, New York.

TRANSFER OF GRADE

Alfred Douglas Edgar, drafting and compilation of data on project of Kansas committee on Relation of Electricity to Agriculture, 1017 Poyntz Avenue, Manhattan, Kansas. (From Student to Junior Member.)

Charles H. Everett, salesman, John Deere Plow Company, 1510 First Avenue North, Fort Dodge, Iowa. (From Student to Junior Member.)

J. Fletcher Goss, graduate fellow, agricultural engineering department, Iowa State College, Ames, Iowa. (From Student to Junior Member.)

F. W. Knipe, head of agricultural engineering department, Connecticut Agricultural College, Storrs, Connecticut. (From Junior Member to Member.)

Darrell B. Lucas, instructor in rural engineering, State University of New Jersey, New Brunswick, New Jersey. (From Junior Member to Associate Member.)

William Joseph Welker, farm engineering instructor, The Provincial School of Agriculture, Claresholm, Alberta, Canada. (From Student to Junior Member.)

A. S. A. E. Employment Service

This service, conducted by the American Society of Agricultural Engineers, appears regularly in each issue of Agricultural Engineering. Members of the Society in good standing will be listed in the published notices of the "Men Available" section. Non-members as well as members, are privileged to use the "Positions Available" section. Copy for notices should be in the Secretary's hands by the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. No charge will be made for this service.

Men Available

AGRICULTURAL ENGINEER, 1923 graduate of Kansas State Agricultural College in agricultural engineering, desires to make a change. Work along engineering lines is preferred. Address M. S. Cook, 5406 Ferdinand Street, Chicago, Illinois. MA-121.

AGRICULTURAL ENGINEER with experience on large farms with all kinds of machinery and equipment wants position with manufacturer of farm equipment. MA-122.

AGRICULTURAL ENGINEER wants position with contractors doing work in farmstead planning and building. MA-123.

AGRICULTURAL ENGINEER open for position as sales engineer, salesman, advertising writer, or agricultural propagandist. Past experience with large agricultural firms. MA-124.

AGRICULTURAL ENGINEER, 1925 graduate of Kansas State Agricultural College, with farm experience, would like permanent employment at once, preferably with a farm-machinery manufacturer. MA-125.

AGRICULTURAL ENGINEER, graduate of Iowa State College, E. E. 1909, A. E. 1910, desires to make change. Ten years experience in field and factory on tractors, trucks, and farm machinery. Five years teaching experience in agricultural engineering and farm mechanics. Instructional work along agricultural engineering lines preferred. MA-126.

Positions Open

ASSISTANT IN AGRICULTURAL ENGINEERING, with specific duties in irrigation and drainage, is wanted by the department of agricultural engineering of the University of Montana, Bozeman. The time is to be divided about half teaching and half experiment station work. The teaching will be at Bozeman and a large part of the station work will be done on the duty of water at a substation with supervisory duties at the substation. The position has responsibilities connected with it that will require mature judgment and some practical experience. The salary will be between $2000 and $2400. Candidates for this position should write Prof. H. E. Murdock, head of the department of agricultural engineering, at the University of Montana.